OE Barricade Guide Development

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ABSTRACT

Barricades are widely used for mitigating the effects of fragmentation from an accidental explosion during the ordnance removal process. Historically, these barricades have been designed for each site as required. The criteria and design parameters for barricades have not been clearly defined and thus the designs and use of barricades vary widely. Barricade designs presently require significant efforts by engineering personnel and, due to the urgencies of many ordnance removal operations, often little time is available.

The U.S. Army Engineering and Support Center, Huntsville (HNC) is developing a guide for design, construction, and use of barricades for explosive ordnance removal operations. The guide includes the use and construction of several aluminum framed portable barricades with several fragment mitigating material types as well as a modular sandbag barricade. The guide will enable field personnel to easily specify and construct the type of barricade to be used, including the type and thickness of fragment mitigating material required. The guide includes specified required thicknesses for eleven commonly encountered munitions. For other munitions, the munition must be analyzed to calculate the design fragment weight and the initial fragment velocity resulting from an accidental explosion and penetration curves may be used to determine the required thickness for various fragment mitigating materials. This will result in a commonality in barricades and reduce the engineering requirement in removal operations.

This paper covers the initial barricade guide development along with the future development plans, including investigation of some other frame materials and potential fragment mitigating materials. This effort is being conducted for the Innovative Technologies Development Program in support of HNC's Ordnance and Explosive Mandatory Center of Expertise (OE-MCX).

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1.0 INTRODUCTION

The U.S. Army Engineering and Support Center, Huntsville (HNC) is currently engaged in projects which require buried ordnance removal. Safety to the public and personnel performing removal operations nearby are of the utmost importance. An accidental explosion produces hazards from primary fragments, blast overpressure and noise.

The Structural Branch, HNC, was tasked by the Ordnance and Explosive Mandatory Center of Expertise (OE-MCX) Innovative Technologies Program to develop a barricade guide to reduce the effects of primary fragments from a suspected buried explosive filled ordnance during removal operations. One method to mitigate primary fragment hazards is to provide barricades which will intercept the low angle, high velocity fragments which have an energy of 58 ft-lbs or higher. The guide provides information on siting and selection of fragment mitigating material to defeat the primary fragments of selected ordnance at Ordnance Explosive (OE) remediation sites. The guide does not address effects from blast overpressure and noise.

The Structural Branch has analyzed various materials and determined thicknesses required to prevent penetration from primary fragments of selected commonly encountered munitions (see Tables 1 - 4). Frames were designed to accept varying thicknesses of the fragment mitigating material selected. The barricades were not intended to be reused after an incident. The thickness required to prevent penetration of the primary fragment from the selected ordnance was calculated using TM 5-1300 [1] and DOE/TIC-11268 [2]. For munitions not listed in Tables 1 - 4, penetration curves are used to determine the required thickness of various fragment mitigating materials based on fragment weight and impact velocity. The impacting fragment is assumed to be mild steel.

Siting of the barricade is based on the burial depth of the ordnance and the soil condition. This will determine if the barricade can effectively reduce the fragment distance and provide safety to the public.

2.0 BARRICADES

The guide covers five types of barricades (plate barricade, box barricade, open front barricade, enclosed barricade, and modular sandbag barricade) that have been designed to be non-reusable after an incident. Barricades may be modified in height and width as required but thickness of the fragment mitigating material must be met for the selected munition.

The type of barricade selected will depend on the buried ordnance that has been identified, site layout, location to the public sector and work plan exclusion zone. Other selection factors include the material cost and availability, weight of frame and fragment mitigating material, time for assembly/disassembly and transportation to the site.

These barricades are limited by the terrain of the site. Users of these barricades must take this into consideration when selecting the barricade that will meet the safety criteria per DAPAM 385-64 [3] and DOD 6055.9-STD [4].

Table 1 - Munition Definition, Design Fragment Weight & Initial Velocity

Munition	Explosive Type	Explosive Weight (lb)	Length of Projectile (in)	Design Fragment Weight (lb)	Initial Velocity (ft/sec)
20 mm M56A4	H761 (RDX)	0.0264	2.115	0.000106	3183
37 mm MKII	TNT	0.53	5.92	0.026868	2060
MK II Grenade	TNT	0.125	4.50	0.014217	3425
40 mm MK2 Grenade	TNT	0.187	6.068	0.013709	2898
60 mm M49A3	Comp B	0.42	5.02	0.006211	5114
75 mm M48	TNT	1.47	11.226	0.053392	2692
81 mm M374	Comp B	2.10	10.365	0.005055	6721
105 mm M1	Comp B	5.08	15.70	0.043224	4055
155 mm M107	Comp B	15.40	23.81	0.15413	3426
4.2 in M3A1	TNT	8.165	15.833	0.013086	6391
3 in Stokes	TNT	2.10	14.25	0.006829	6189

Table 2 - Horizontal Range of Fragments		
Munition	Maximum Horizontal Range (ft)	Horizontal Range of 58 ft-lb Fragment (ft)
20 mm M56A4	191	N/A
37 mm MK II	880	403
MK II Grenade	842	341
40 mm MK2 Grenade	798	309
60 mm M49A3	723	243
75 mm M48	1166	695
81 mm M374	716	246
105 mm M1	1224	719
155 mm M107	1699	1372
4.2 in M3A1	944	428
3 in Stokes	772	284

Table 3 - Penetration of Concrete, Sand and Wood				
Munition	4000 psi Concrete		Sand	Dry Pine
	Minimum Thickness to Prevent Perforation (in)	Minimum Thickness to Prevent Spall (in)	Penetration Depth (in)	Minimum Thickness to Prevent Perforation (in)
20 mm M56A4	0.30	0.37	0.83	0.57
37 mm MK II	3.19	3.68	4.64	8.60
MK II Grenade	2.08	2.54	4.42	9.39
40 mm MK 2 Grenade	1.77	2.17	4.01	8.59
60 mm M49A3	2.40	2.81	4.01	6.92
75 mm M48	3.11	3.76	6.13	18.01
81 mm M374	3.23	3.68	4.17	6.89
105 mm M1	4.11	4.79	6.93	18.91
155 mm M107	5.86	6.82	9.77	36.27
4.2 in M3A1	4.46	5.09	5.62	11.58
3 in Stokes	3.25	3.73	4.47	7.90

Table 4 - Penetration of Steel, Aluminum & LEXAN Using THOR Equations				
Munition	Minimum Thickness to Prevent Perforation (in)			
	Mild Homogeneous Steel	Hardened Homogeneous Steel	2024 T-3 Aluminum	LEXAN
20 mm M56A4	0.069	0.057	0.17	1.10
37 mm MK II	0.68	0.56	1.45	4.42
MK II Grenade	0.47	0.39	1.00	3.78
40 mm MK 2 Grenade	0.40	0.33	0.86	3.41
60 mm M49A3	0.53	0.43	1.14	3.85
75 mm M48	0.70	0.58	1.45	4.82
81 mm M374	0.66	0.54	1.43	4.26
105 mm M1	0.90	0.74	1.87	5.44
155 mm M107	1.27	1.05	2.59	6.76
4.2 in M3A1	0.91	0.75	1.93	5.22
3 in Stokes	0.68	0.56	1.46	4.38

The plate barricade (Figure 1) consists of an aluminum frame with plate materials attached to intercept fragments. The plate barricade presents a frontal area of 40 square feet (4 feet wide by 10 feet high). Plate materials include aluminum, wood, steel (mild and hardened) and LEXAN. The frame is designed to be assembled and disassembled in the field by equipment and transported to the next buried ordnance removal site. It can be left intact and moved with a crane, forklift or other heavy equipment. The assembled frame weighs approximately 1500 pounds.

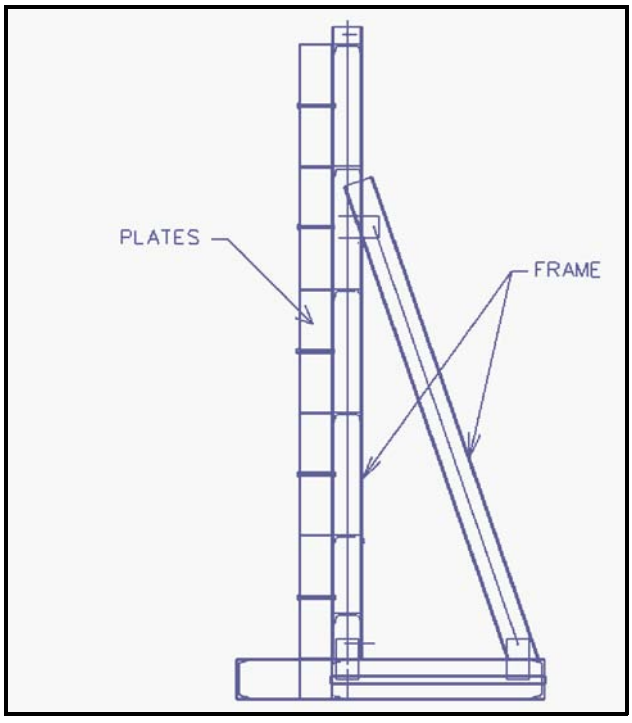

Figure 1 - Plate Barricade

The box barricade (Figure 2) consists of an aluminum frame with an aluminum box in which various materials may be stacked. The box barricade presents a frontal area of 40 square feet (4 feet wide by 10 feet high). The materials to be considered are non-plate materials such as concrete blocks, sandbags and bricks. The frame can be assembled and disassembled in the field by equipment and transported to the next site. The fragment mitigating non-plate materials must be loaded after barricade is sited and unloaded prior to moving to the next site. The assembled frame weighs approximately 850 pounds.

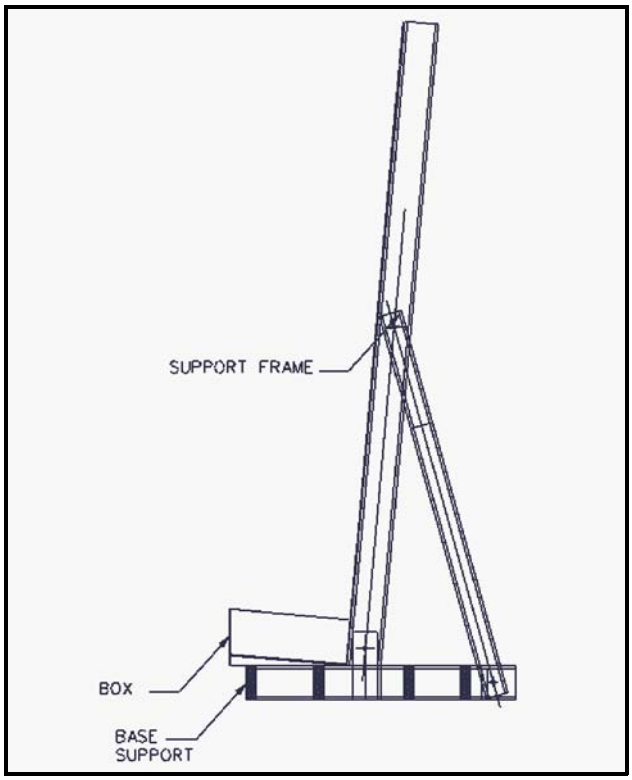

Figure 2 - Box Barricade

The plate and box barricades are designed to mitigate fragments up to 70 degrees from point of detonation. High angle fragments will clear the top of the barricades but at a reduced downrange distance. The number of barricades and arrangement will depend on the site condition, location of the buried munition in relation to the surroundings and the primary fragment distance of the munition. Plate barricades may be located side-to-side to effectively increase the horizontal range coverage. The box barricade must be used singly to determine the horizontal range coverage due to the construction method.

The plate and box barricades may be used on slopes not exceeding 10%. When locating two or more plate barricades side to side, the barricades should be lapped to prevent primary fragments from escaping through any openings.

The open front barricade (Figure 3) consists of an aluminum frame with aluminum panels on three sides and the roof. The inside dimension is 4 feet by 4 feet by 6 feet high. The frame is designed to be assembled and disassembled in the field. The plate materials must be assembled and disassembled prior to relocating to the next site. The assembled frame weighs approximately 60 pounds.

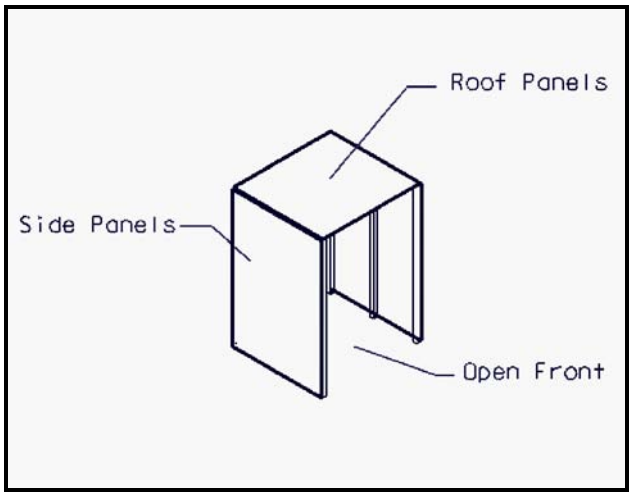

Figure 3 - Open Front Barricade

The open front barricade is designed to mitigate fragments from the list of selected munitions in Table 1. This barricade does not

intercept any fragments from the open front.

The enclosed barricade (Figure 4) consists of an aluminum frame with aluminum panels on three sides, roof, canopy and front barricade. The inside dimension is 4 feet by 4 feet by 6 feet high. The frame is designed to be assembled and disassembled in the field. The plate materials must be assembled and disassembled prior to relocating to the next site. The assembled frame weighs approximately 120 pounds.

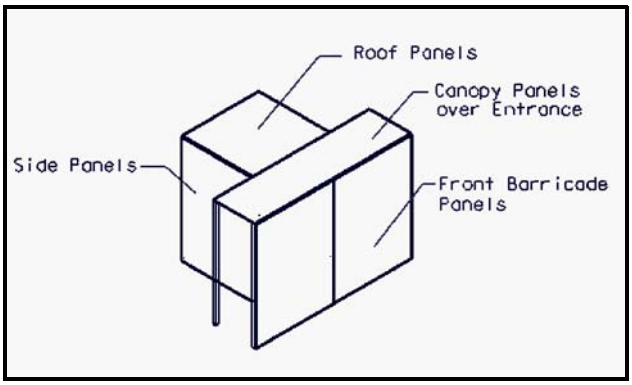

Figure 4 - Enclosed Barricade

The enclosed barricade is designed to mitigate fragments from the list of selected munitions in Table 1. This barricade provides for complete fragment containment as it has a front barricade and a canopy over the entrance.

The open front and enclosed barricades have adjustable legs and may be used on slopes not exceeding 30%. Any opening at the base should be covered with the same plate thickness or equivalent thickness of sand (sandbags). The barricade is to be located over the buried munition.

The modular sandbag barricade (Figure 5) consists of sandbags on a custom wooden pallet and banded by a nylon strap. The barricade may be modified by deletion of the roof and/or the front wall modules. The inside dimension is 6 feet by 6 feet by 4 feet 3 inches high.

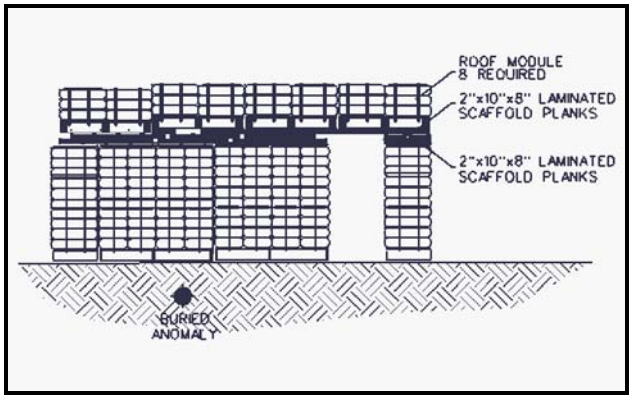

Figure 5 - Sandbag Barricade

The modular sandbag barricade is designed to mitigate the primary fragments from the ordnance listed in Table 1, Appendix A. This barricade will provide complete fragment containment provided it is constructed as shown in Figure 5. The modular sandbag barricade may be modified to suit the site condition and the exclusion zone.

The modular sandbag barricade cannot be used on any sloping terrain and should be used on a very level site. It requires a heavy machinery that is able to place and remove the modules. The barricade is to be located over the buried munition.

3.0 FRAGMENT MITIGATING MATERIALS

The materials selected for this study are based on materials that are readily available. Tables

1 - 4 identify the selected munition, calculated fragment weight and velocity per TM 5-1300 [1], fragment ranges per computer code TRAJ [5] and penetration of various materials based on mild steel fragment per DOE/TIC-11268 [2]. If a munition other than those listed is identified, primary fragment weight and velocity must be calculated using procedures in TM 5-1300 [1] and required material thicknesses must be calculated using penetration equations from DOE/TIC-11268 [2].

The fragment penetration of the various materials is based on worst case normal impact obliquity. Impacts of other obliquities present a greater thickness to penetration but are not taken into account due to the wide range of factors affecting the obliquity such as depth of burial, horizontal distance from the munition to the barricade, etc.

4.0 CONCLUSIONS

Five barricades have been discussed. These barricades are for fragment mitigation only. The effects of these barricades on overpressure and noise have not been considered but it is unlikely that any of the barricades will have any effect on overpressure or noise. All of the barricades have been designed for total capture of all primary fragments striking the barricade. If the user wishes only to reduce the required withdrawal distance due to fragment throw, the fragment mitigating material thickness must be designed on a case-by-case basis.

The barricades that will completely contain the primary fragments are the enclosed barricade and the modular sandbag barricade with roof and front barricade. These will produce zero (0) fragment distance. The next most effective barricade is the open front barricade which would project primary fragments out the open end only. The plate and box barricades would produce a pie-shaped area where no primary fragments (except those that travel over the barricade) would impact.

Based on the location of suspected buried ordnance, the safety personnel must determine the risk to the public and nearby personnel completing removal actions. This will determine which barricade will be the most effective in reducing the risk of injury or damage to the public sector. A risk assessment must be conducted prior to determining type of barricade required to minimize primary fragment impact.

The open front, enclosed, and modular sandbag barricades should be located directly over the buried ordnance that will be excavated. The plate and box barricades should be located as close to the edge of the hole that is to be excavated as possible to be most effective. However, the toe of the plate or box barricade should be at least one foot from the edge of the hole. This is to prevent these barricades from becoming a hazard to personnel during the removal operation.

It is recommended that other frame materials, fragment mitigating materials and designs be investigated to develop a lightweight and portable barricade. Other possible frame materials are PVC pipes and fiberglass. Modular designs which will minimize assembly and disassembly time, portability and ease of use on various terrain need to investigated.

5.0 REFERENCES

1. ARMY TM 5-1300, Structures to Resist the Effects of Accidental Explosions, November 1990.

2. DOE/TIC-11268, A Manual for the Prediction of Blast and Fragment Loadings on Structures, February 1992.

3. Department of the Army Pamphlet 385-64, Ammunition and Explosives Safety Standards (Draft).

4. Department of Defense 6055.9-STD, DOD Ammunition and Explosives Safety Standards, October 1992.

5. "TRAJ--A Two Dimensional Trajectory Program for Personal Computers", Minutes of the Twenty-Fourth Explosives Safety Seminar, August 1990, pp. 1853-1879, Montanaro, P.E.